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THE EXPLOSIBILITY OF DUSTS FROM THREE SULPHIDE ORE CONCENTRATES

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THE EXPLOSIBILITY OF DUSTS FROM THREE SULPHIDE ORE CONCENTRATES

by

K.J. Mintz*

ABSTRACT

The minimum explosible concentration, maximum explosion pressure, maximum rate of pressure rise, and minimum ignition temperature were measured on dust samples from three Canadian mines. The 20 L vessel was used for the first three measurements and the Godbert-Greenwald furnace for the last-named. Explosion tests were also carried out on the finest (-325 mesh) fraction.

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KEYWORDS: dust, explosibility, sulphides, ore concentrates

EXPLOSIBILITÉ DES POUSSIÈRES PROVENANT DE TROIS CONCENTRÉS DE MINERAIS SULFURÉS

par

K.J. Mintz*

RÉSUMÉ

La concentration minimale explosible, la pression maximale d'explosion, le taux maximal d'élévation de pression, et la température minimale d'allumage ont été mesurés à l'aide de trois échantillons provenant des exploitations de la Noranda. Un récipient de 20 L a servi lors des trois premières mesures et un four Godbert-Greenwald pour la dernière mesure susmentionnée. On a aussi réalisé des essais d'explosion avec la fraction la plus fine, soit à la maille de -325.

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Mots-clés: poussières, explosibilité, sulfures, concentrés de minerais

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INTRODUCTION

During the past year, Norand: Research and CANMET have been carrying out a joint study of the explosibility of sulphide ore dusts, because of the increased awareness of their hazards in underground mines (1). Noranda Research has decided to extend this work to cover the dust explosibility of chalcopyrite concentrates in order to evaluate the hazards of drying and air conveying.

Two sets of samples from three Canadian mines, designated "A", "B" and "C", were sent by Noranda Research. This report provides the results of testing for the maximum explosion pressure/maximum rate of pressure rise, the minimum explosible concentration (m.e.c.), and the minimum ignition temperature (m.i.t.).

APPARATUS

In our earlier study (1), the Hartmann apparatus was used, modified to allow tests to be carried out in pure O_2. (Sulphide ore dusts are too insensitive to be ignited in air using an electrical discharge.) This study employed the CANMET version of the 20 L vessel, developed originally by the U.S. Bureau of Mines. It has recently been commissioned and is described fully elsewhere (2,3). Briefly, air at a high pressure is released through a solenoid valve and disperses dust from a small chamber into the previously evacuated 20 L vessel. After

the dust is dispersed, an ignition source ignites the dust cloud. A digital oscilloscope records the signal from a strain-gauge pressure transducer mounted on the vessel. The most important advantage of the 20 L vessel with respect to sulphide dust explosibility testing is that it accommodates more powerful ignition systems, in particular, the Sobbe chemical ignitor. Thus, these tests were able to be carried out in ordinary air rather than in oxygen. Other advantages are the more realistic size, the capacity to be evacuated, the possibility of sampling post-explosion gases, and an improved dust dispersion system.

During the course of this study, a paramagnetic oxygen analyzer was refurbished and attached to the 20 L vessel (4). This system allowed measurement of the oxygen remaining in the vessel after an explosion test for several of these tests.

The minimum ignition temperature of the sulphide ore dust cloud was measured by the Godbert-Greenwald furnace, developed by the U.S. Bureau of Mines (5). A modified version of the apparatus has recently been built and commissioned by CANMET (6).

PROCEDURES

Explosion tests in the 20 L vessel were carried out by the following procedure:

1. The sample was weighed and placed in the dust dispersion chamber;
2. The 5 kJ Sobbe chemical ignitor was placed in the centre of the vessel;

3. The vessel was closed and evacuated to 0 kPa absolute;
4. The dust dispersion air chamber was pressurized to 1100 kPa;
5. The solenoid open time was set to 330 ms so as to produce a pressure of 101 kPa absolute inside the vessel immediately after the dust is dispersed;
6. The ignition time was set so that the ignitor would fire 100 ms after the solenoid closes;
7. The firing button was pressed which automatically sequenced the events and triggered the digital oscilloscope which recorded the pressure trace.
8. After the vessel has cooled down, the post-combustion gases were pumped through the oxygen analyzer.

The chemical ignitor produces a significant overpressure by itself in the absence of any dust. Figure 1 shows the pressure trace (lower curve) and its derivative (upper curve) for the ignitor. Horizontal ticks are 500 ms apart, vertical ticks 136 kPa apart (pressure) and 0.34 Mpa/s apart (derivative). The first pressure rise is due to the air for dispersing the dust and raising the pressure up to one atmosphere. The small blip is electrical pick-up from the relay that closes the solenoid valve. The second, very steep rise is due to the ignition of the chemical ignitor. The gases cool down slowly (in the time frame of the experiment), producing a long tail.

In order to determine the pressure trace due to the dust-air explosion, it is necessary to subtract the pressure trace due to the chemical ignitor from the experimental raw trace. To do that, the two traces are moved horizontally and vertically (using programs down-loaded into the digital

oscilloscope) until they coincide exactly at the beginning of the ignition of the ignitor. Then, they are subtracted using a built-in function in the oscilloscope.

An example is shown in Fig. 2. The raw pressure trace (solid line) can be seen to comprise three pressure rises: the first due to the air entering the vessel, the second to the chemical ignitor, and the third to the dust-air explosion. Subtracting off the chemical ignitor curve (Fig. 1) virtually eliminates the first two pressure rises, and allows accurate measurement of the parameters. The derivative curves of the raw and net pressure traces are shown in the upper half of Fig. 2. (The vertical axis for these is expanded four times that in Fig. 1.)

The m.i.t. tests were carried out by the following procedure:

1. 0.1 g of sample was placed in the dust holder;
2. The oven was heated to an initial temperature of 600°C;
3. The air chamber was pressurized to 100 kPa gauge, and the solenoid open time set to 100 ms.
4. With the room lights off, the start button was pressed and observations made as to any sparks coming out the bottom of the furnace.
5. The temperature of the furnace was lowered in 10°C increments until there were no sparks observed in four trials.
6. At this temperature, several tests were carried out with a larger sample and different pressures, to ensure that the true m.i.t. had been reached.

RESULTS AND DISCUSSION

Samples

The first set of dust samples, labelled "-20", presumably meaning that they had been screened through a 20 mesh screen, were insufficient to carry out all the explosion tests required. A second set of dust samples had a substantially different appearance. Not only did they require drying but their sieve analyses were significantly different, being somewhat coarser (see Table 1). It was decided to determine the "worst-case" for the second set, that is, use the finest (-325 mesh) fraction and compare those results with the results from the first set. The m.i.t. tests were carried out using the first set.

Explosion Tests

The results of all the tests are given in Tables 2 - 4. "P_i" is the initial pressure in the 20 L vessel at the time of ignition of the chemical ignitor. "P_m(net)" is the maximum pressure due to the dust-air explosion. "t_m" is the time from the beginning of the ignition to the maximum pressure. "$(dp/dt)_m$" is the maximum rate of pressure rise, which usually occurred at about half of t_m. "Conc. O_2" is the concentration of oxygen in the vessel after the test.

The variation in P_i is primarily due to the resistance of the dust to the air flow. In tests carried out on lycopodium (3), it was shown that P_m is approximately proportional to

P_i. For accurate work, it is necessary to use this correction factor, or vary the solenoid open time so as to have P_i exactly 101 kPa. For the accuracy of the tests reported here, this correction is not required.

Pressure traces, for several concentrations of each of the samples, are shown in Fig. 3 - 5. When the chemical ignitor (or other high-energy ignition source) is used, a pressure rise due to burning of the dust, which is not a self-propagating explosion, is observed. The P_m data, plotted as a function of concentration (see Fig. 6 - 8) is an S-shaped curve. Only the upper part of the curve is in the true explosion region. Hertzberg and Cashdollar (2) have proposed that P_m must be twice P_i (which corresponds to 100 kPa in this study) in order to be a true explosion. This point is approximately mid-way up the steep part of the S-shaped curves in our data. Hence, the minimum explosible concentrations (in g/m^3) are:

	m.e.c.	
	sample #1 - as rec'd	sample #2 -325 mesh
Mine "A"	400	400
Mine "B"	550	550
Mine "C"	950	350

The precision of the m.e.c. is about ± 50 g/m^3 for these samples by this method. Mine "C" is the only one that shows a significant difference in m.e.c. between sample #1 and #2. The difference may possibly be due to "C" samples being coarser than the others. The difference between the Mine "A" and

Mine "B" m.e.c. is well outside the experimental uncertainty.

The maximum explosion pressure (kPa) can be determined from these same curves:

	P_m (kPa)	
	sample #1 - as rec'd	sample #2 -325 mesh
Mine "A"	200	180
Mine "B"	190	230
Mine "C"	220	220

Due to the rather large scatter, which is not due to the experimental method, but is probably due to the inhomogeneity of the sample, the precision of P_m ranges from ± 5 to ± 20 kPa. The differences amongst the values in the above table are not great, and are probably not worthy of excessive interpretation. Normally, one would expect that finer dusts would give higher P_m, but the above results do not support that concept for these materials. It is important to note that the two Mine "C" samples yielded the same P_m despite considerable difference in the m.e.c. Fig. 8 would seem to suggest that the larger size fractions were not contributing to the explosibility, but that if a sufficiently large portion of sample #1 were taken, then there would be enough of the fines present to produce a full explosion.

Most explosible dusts yield P_m in the 500 - 800 kPa range, but some have been reported in the range of these concentrate dusts (7).

Normally, $(dP/dt)_m$ is measured with much lower accuracy than P_m. The concentrate dusts are no exception to

this rule. Figures 9 - 11 show $(dP/dt)_m$ as a function of concentration. Most of the curves do not show the distinct S-shape that the P_m vs. concentration curves showed. The estimated maxima (in MPa/s) are as follows:

	$(dp/dt)_m$ (Mpa/s)	
	Sample #1 - as rec'd	Sample #2 -325 mesh
Mine "A"	1.9 (?)	1.4
Mine "B"	1.0	2.2
Mine "C"	1.8	2.0

The question mark indicates the value was based on a single point, and is therefore subject to some uncertainty. The increase in $(dp/dt)_m$ is greater going from the whole sample to the -325 mesh fraction than was the case for P_m (in the case of Mines "B" and "C").

The measured oxygen concentrations in Tables 2 - 4 correlate well with the P_m: at low dust concentrations, which produced low P_m, the O_2 was not depleted. At higher dust concentrations, which produced higher P_2, most of the O_2 was consumed.

Minimum Ignition Temperature

The m.i.t. of sample #1 were as follows (in °C):

Mine "A"	520
Mine "B"	540
Mine "C"	540

Unlike most other flammable materials, a flame is not observed exiting the furnace; rather, individual sparks appear. These are most likely created by the smallest particles in the sample; therefore, it would be expected that there would not be very much difference between whole sample and the -325 mesh fraction. This hypothesis remains to be proven out. Although the difference between Mine "A", on the one hand, and Mines "B" and "C" on the other, is outside the experimental error, it is sufficiently small that the degree of hazard represented by the m.i.t. test can be considered to be the same. We had previously measured the m.i.t. of pure chalcopyrite as 480°C (6). Presumably, the presence of some inert materials in the concentrates may have raised the m.i.t. slightly.

CONCLUSIONS

The four standard experimental parameters of three sulphide ore dusts were measured. Although the Mine "A" dust was slightly more hazardous based on the minimum explosible concentration and the minimum ignition temperature, its explosion pressure and rate of pressure rise were in the same range as the other two dusts. If samples #1 were indeed representative of the actual dust produced, then Mine "C" would be much less hazardous, almost solely on the basis of having a larger mean particle size. Because of the large differences between samples 1 and samples 2, this conclusion should be treated with caution. It should also be noted that the ignitor used was a very energetic one; ordinary

sparks would be insufficient to ignite these dusts. Flames or hot surfaces, however, would have the potential of igniting dust clouds formed from these materials.

REFERENCES

1. Mintz, K.J., Saindon, J.P., Wheeland, K.G., and Kieller, B.J. "An investigation into the relationship between the explosibility and mineralogy of sulphide ore dusts", presented to the 90th Annual General Meeting of the Canadian Institute of Mining and Metallurgy; 1988.
2. Cashdollar, K.L. and Hertzberg, M., Rev.Sci.Instrum. 56, 596;1985.
3. Mintz, K.J. "Commissioning of the 20 L vessel for studying dust-air explosions", CANMET Div. Rep. MRL 88-32(TR);1988.
4. Judge, K.J. "Installation and use of an oxygen analyzer for the 20 L explosion vessel", CANMET Div. Rep. MRL 88-51 (TR);1988.
5. Dorsett, H.G. et al. "Laboratory equipment and test procedures for evaluating the explosibility of dusts", U.S. Bureau of Mines RI5624;1960.
6. Mintz, K.J. and Judge, K.J. "Commissioning and use of the minimum ignition temperature apparatus for dust clouds", CANMET Div. Rep. 88-55 (TR);1988.
7. Field, P. "Dust Explosions", Elsevier, New York, pp.205-220; 1982

Table 1. Screen analysis of concentrate dust samples

(% by weight)

screen	Mine "A"		Mine "B"		Mine "C"	
	#1	#2	#1	#2	#1	#2
+20	0.0	5.8	0.0	0.7	0.0	0.0
-20/+200	6.3	46.3	11.0	34.9	13.8	18.4
-200/+325	16.0	19.6	20.1	23.2	28.0	28.8
-325	77.7	28.3	68.9	41.1	58.2	45.0

Table 2. Explosion tests on Mine "A" concentrates

Conc. (g/m^3)	P_i (kPa)	P_m(net) (kPa)	t_m (ms)	$(dp/dt)_m$ (MPa/s)	conc.O_2 (%)
		Mine "A" sample #1 - as received			
200	98	34	350	0.18	--
250	98	26	194	--	--
300	101	56	318	0.45	--
400	99	65	286	0.48	--
500	98	162	315	0.66	--
600	99	209	242	1.93	--
700	96	178	265	1.20	--
700	96	214	229	1.26	4.1
		Mine "A" sample #2 -325 mesh			
272	100	9	--	--	17.5
500	98	151	300	0.75	--
750	99	189	226	1.26	--
1025	96	184	198	1.38	5.4

Table 3. Explosion tests on Mine "B" concentrates

Conc. (g/m^3)	P_i (kPa)	P_m(net) (kPa)	t_m (ms)	$(dp/dt)_m$ (MPa/s)	conc.O_2 (%)
		Mine "B" sample #1 - as received			
300	89	9	104	0.35	--
400	92	21	156	0.43	--
500	94	64	194	0.70	--
500	98	46	261	0.41	16.6
600	100	138	286	0.79	11.2
750	97	174	325	0.84	--
1000	100	190	320	0.97	--
		Mine "B" sample #2 -325 mesh			
500	99	30	218	0.47	17.4
600	99	140	351	0.47	11.8
800	100	236	189	2.16	4.8
1000	95	168	357	0.71	--
1065	98	214	226	1.59	3.4
1200	95	235	164	2.54	0.8
1500	96	179	234	1.24	4.7

Table 4. Explosion tests on Mine "C" concentrates

Conc. (g/m^3)	P_i (kPa)	P_m(net) (kPa)	t_m (ms)	$(dp/dt)_m$ (MPa/s)	conc.O_2 (%)
		Mine "C" sample #1 - as received			
500	94	5	--	--	--
750	90	30	160	0.48	--
900	94	54	222	0.15	--
1000	84	173	--	1.18	--
1500	92	226	237	1.75	0.3
		Mine "C" sample #2 -325 mesh			
100	104	4	85	--	--
300	101	27	192	0.48	--
400	98	143	269	0.83	--
500	97	171	271	0.99	--
932	99	208	189	1.95	--
1250	96	222	217	1.56	--
1400	94	227	158	2.38	--
1500	94	223	215	1.63	--

FIG.1.PRESSURE TRACE OF THE CHEMICAL IGNITOR AND ITS DERIVATIVE

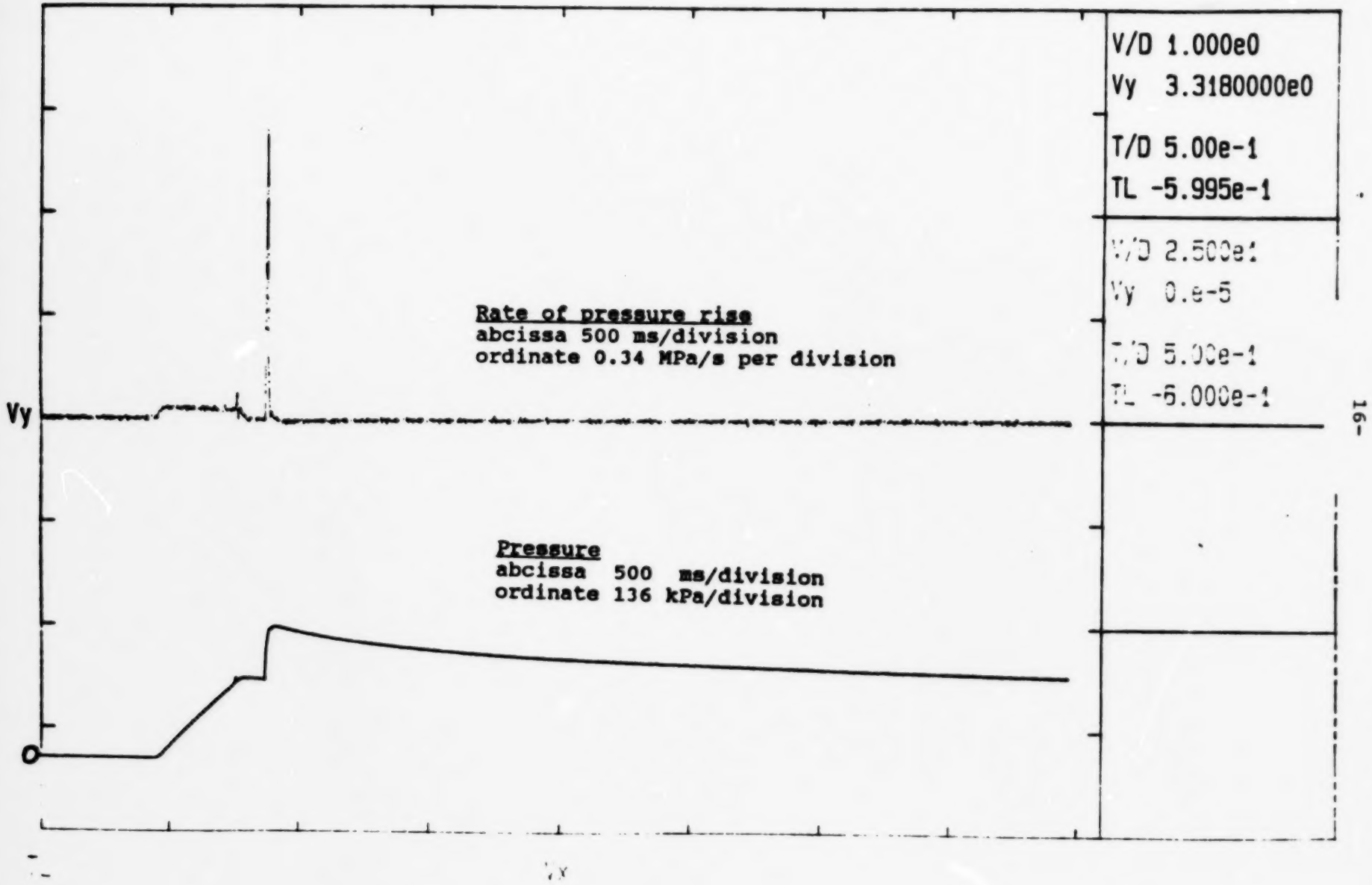


FIG.2.RAW AND NET PRESSURE AND DERIVATIVE CURVES FROM A TYPICAL TEST

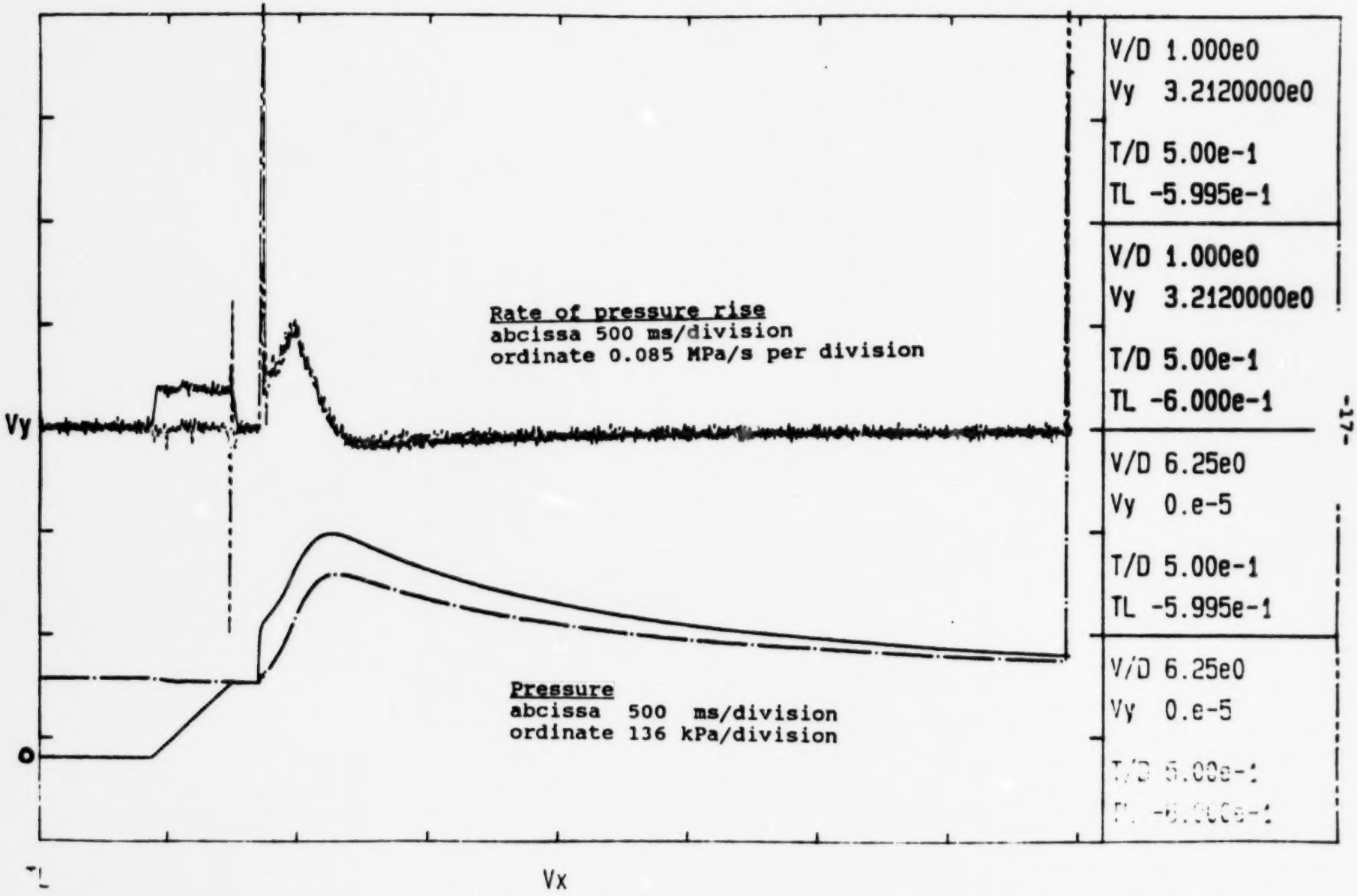


FIG.3.PRESSURE TRACES FOR MINE "A" CONCENTRATE DUST AT 400, 500 & 600 G/M^3

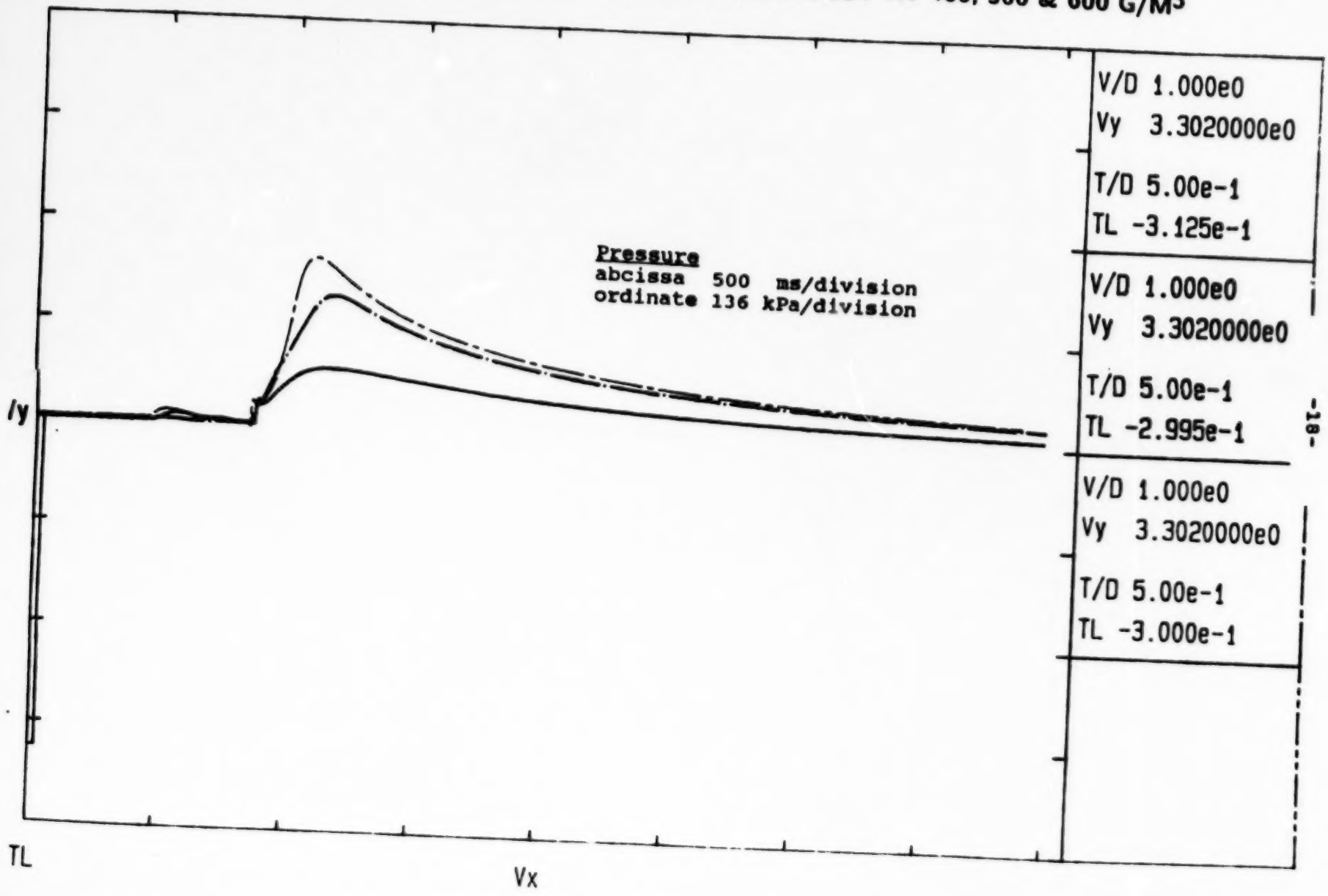


FIG.4.PRESSURE TRACES FOR MINE "B" CONCENTRATE DUST AT 500,600,750 & 1000 G/M^3

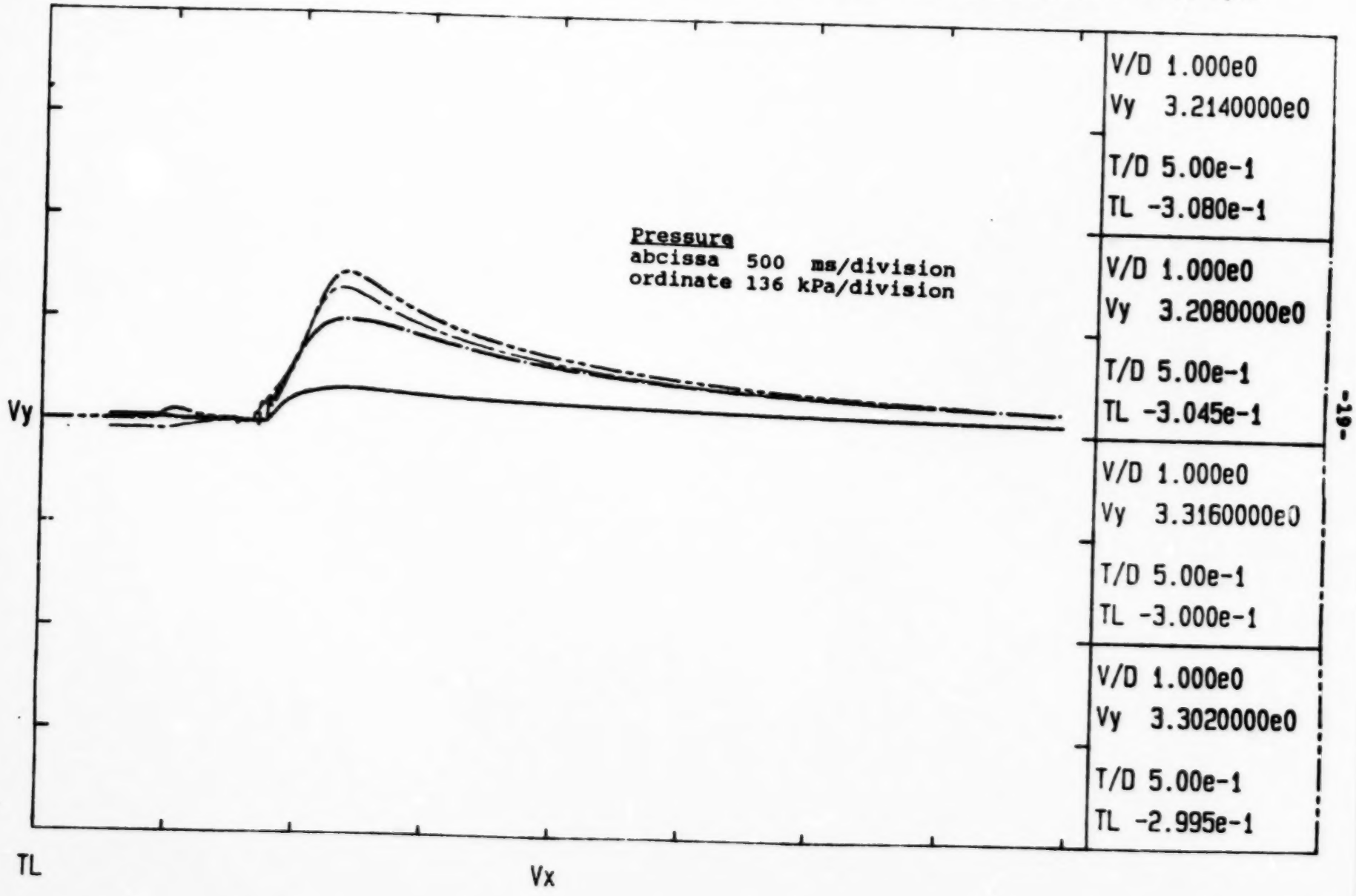


FIG.5.PRESSURE TRACES FOR MINE "C" CONCENTRATE DUST AT 750,1000,1500 G/M^3

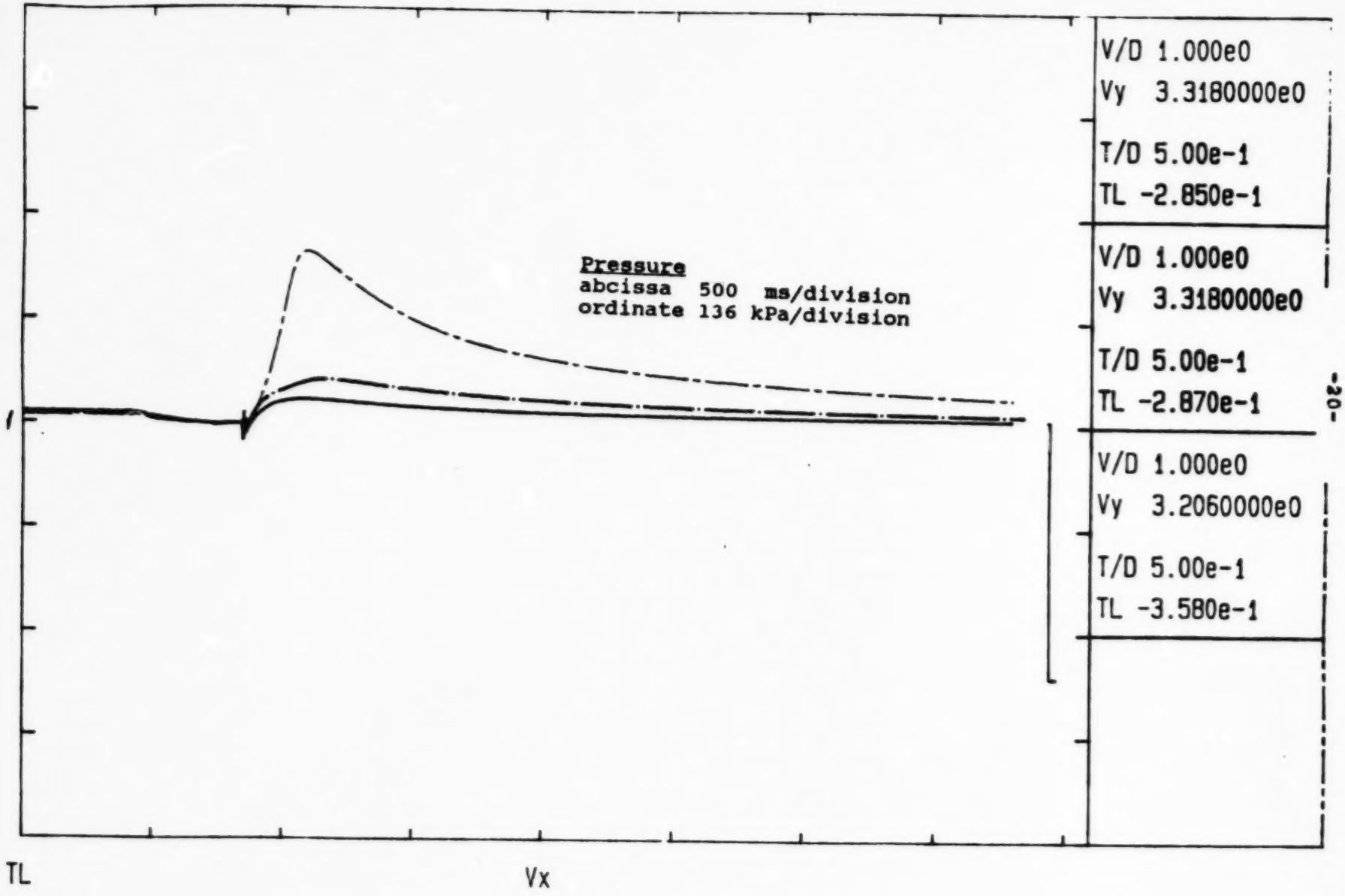


FIG.6. EXPLOSION PRESSURE: MINE "A" CONCENTRATE DUST

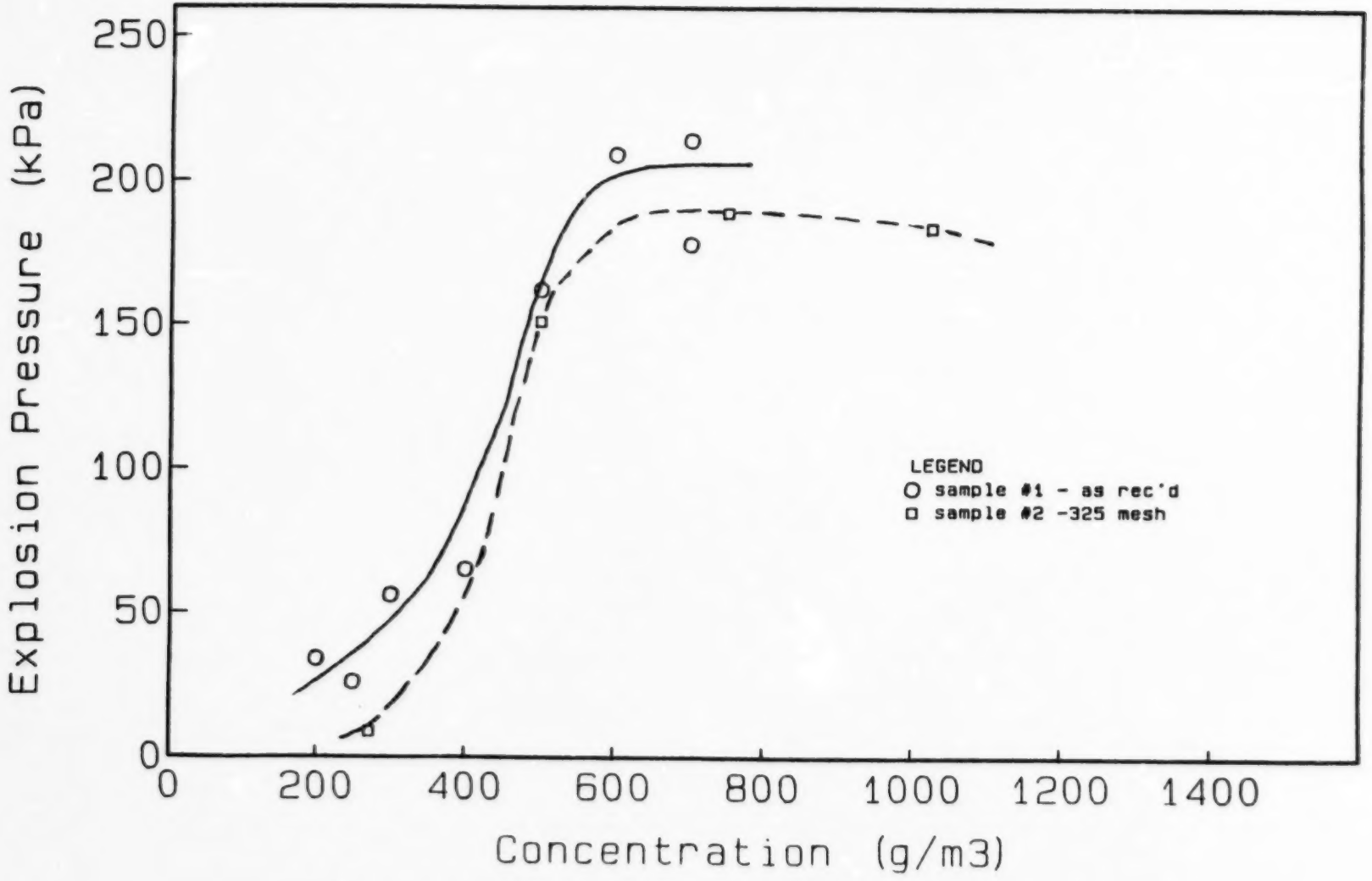


FIG.7. EXPLOSION PRESSURE: MINE "B" CONCENTRATE DUST

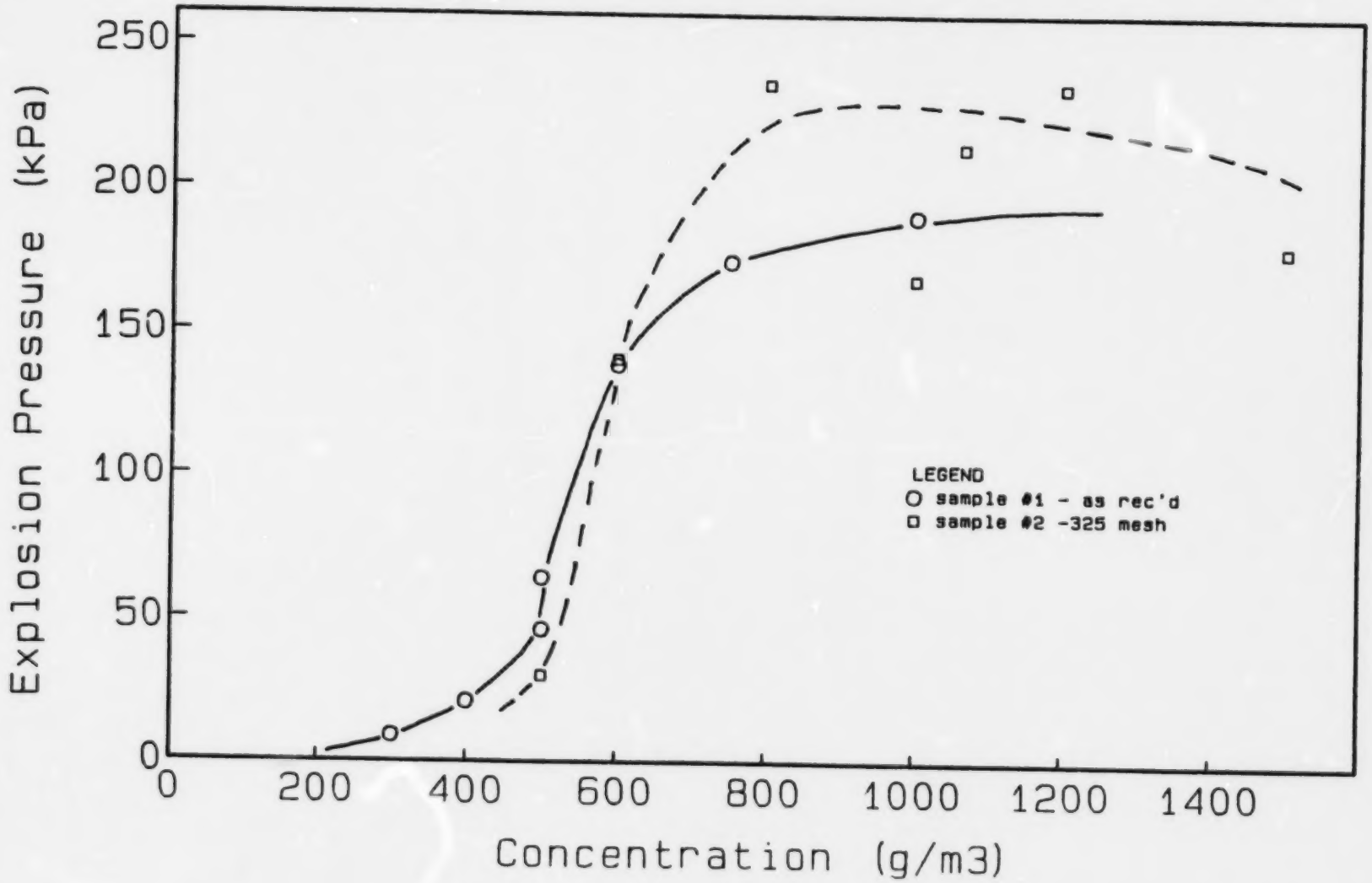


FIG.8. EXPLOSION PRESSURE: MINE "C" CONCENTRATE DUST

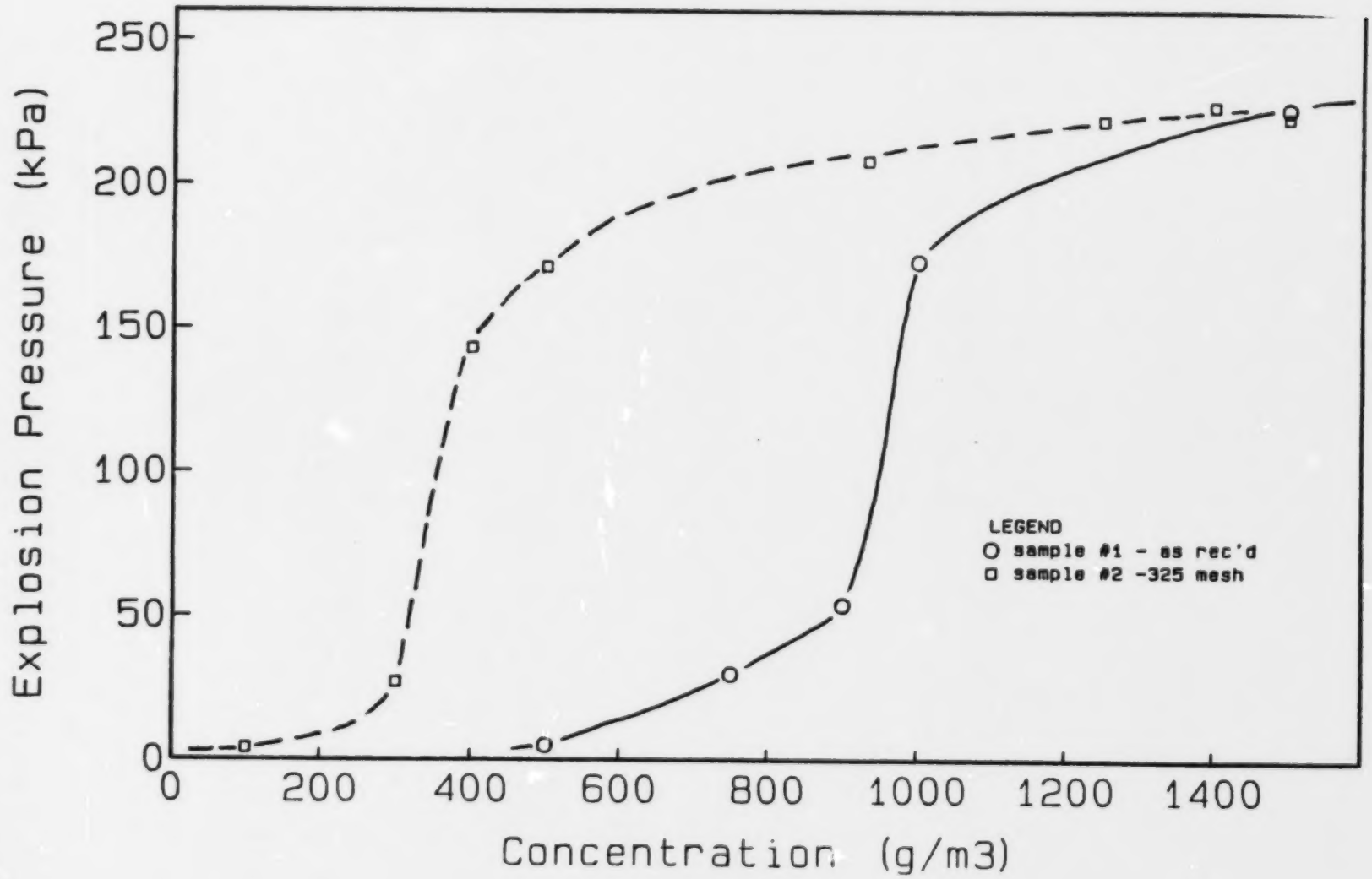


FIG.9. RATE OF PRESSURE RISE: MINE "A" CONCENTRATE DUST

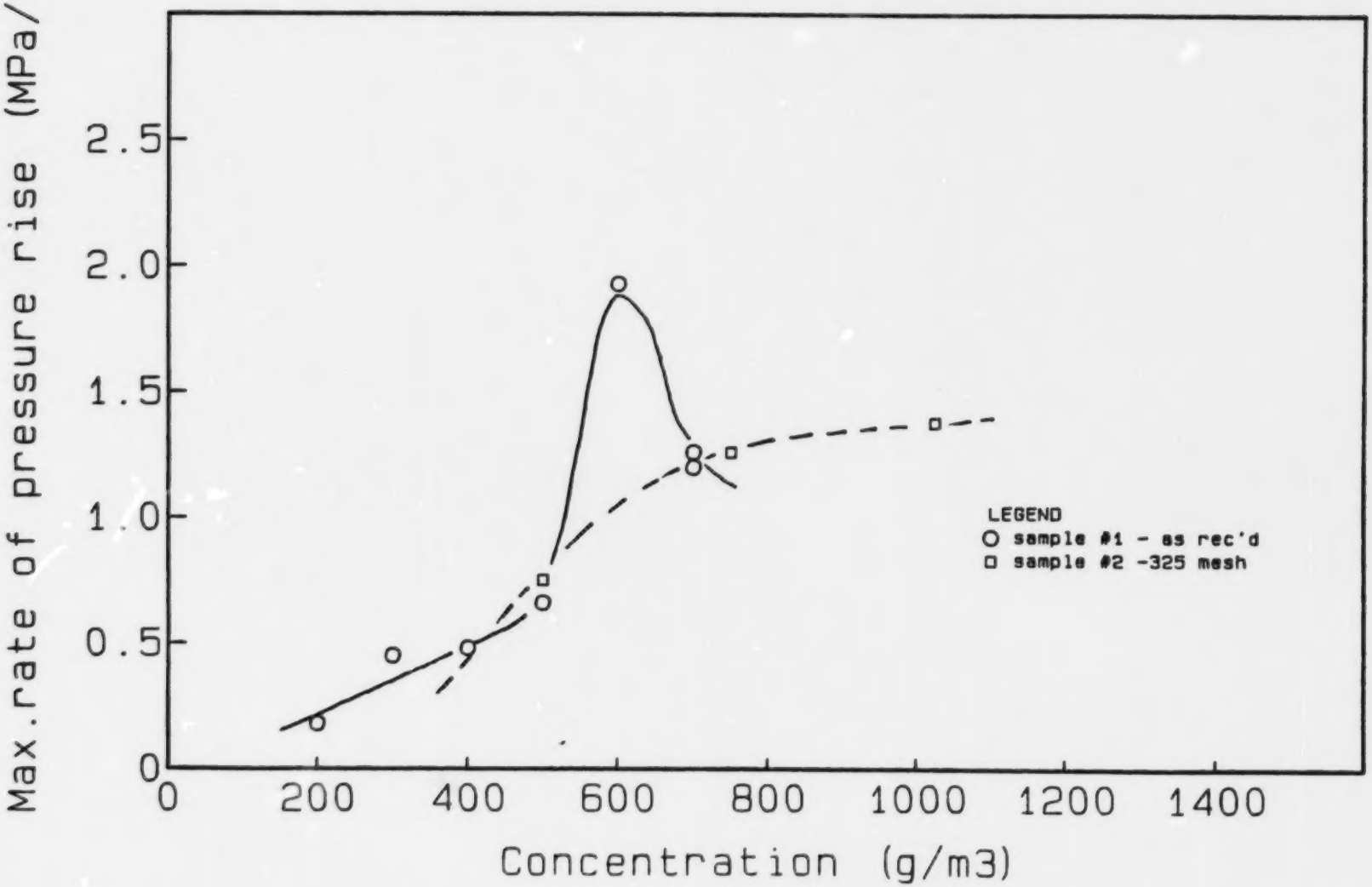


FIG.10. RATE OF PRESSURE RISE: MINE "B" CONCENTRATE DUST

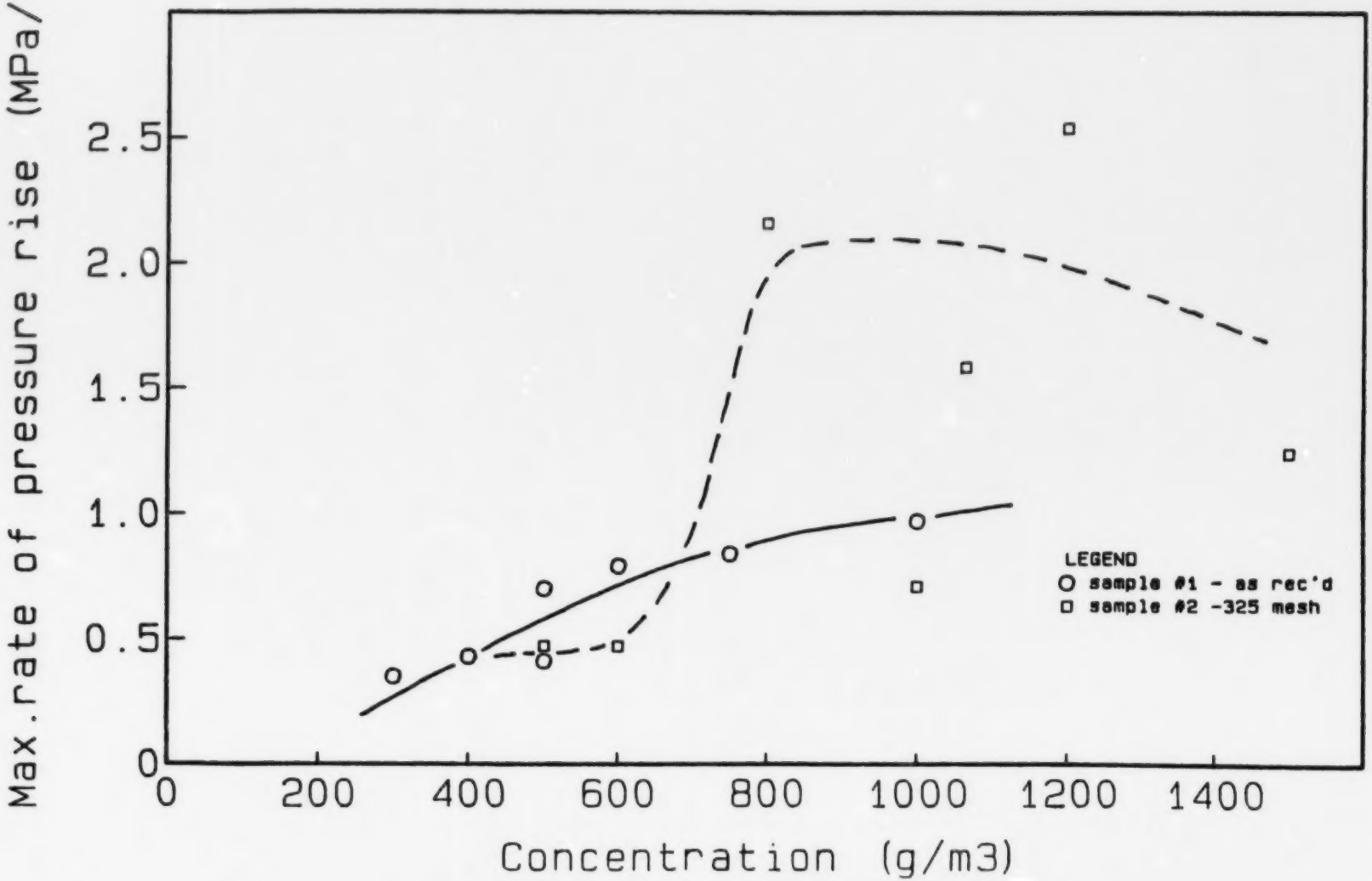


FIG.11. RATE OF PRESSURE RISE: MINE "C" CONCENTRATE DUST

